SOME HYDROLOGIC ASPECTS OF PROPOSED COAL MINING IN THE NORTH FORK OF THE FLATHEAD RIVER HEADWATERS AREA, NORTHWEST MONTANA AND SOUTHEAST BRITISH COLUMBIA

MONTANA
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ABSTRACT

An open-pit coal mine has been proposed by Sage Creek Coal Ltd. in the North Fork of the Flathead River headwaters area, British Columbia, six miles north of the International Boundary. Extensive environmental assessments of the development have been conducted during exploration and permitting phases, but potentials for acid mine drainage and for increased dissolved solids in leachates were not specifically addressed.

In this study, overburden and interburden samples from two British Columbia mines both,in a geologic setting assumed representative of the Sage Creek Project, were evaluated for acid consumption/production potential. Stratigraphic thickness of Jurassic-Cretaceous Kootenay beds used for analysis was 600 feet at one mine, and 750 feet at the other. For both sets of samples, results indicated no potential for production of acid mine drainage. With the assumption that these strata are geochemically representative of those at the proposed project, it can be concluded that mine drainage there will be slightly acidic to alkaline, much like drainages from other southern British Columbia and Alberta mines.

Potential for increased off-site dissolved-solids concentrations was evaluated by mass-balancing hypothetical mine-dump leachates into selected flows of Howell Creek and the North Fork of the Flathead River. Assumptions were that recharge rates to mine dumps would range between 1 and 5 inches per year, and that resulting leachates would contain four-times the dissolved-solids contents that occur in pre-mining ground water. Results suggested that increases in dissolved solids in the river at the International Boundary would be so low as to be undetectable, but Howell Creek pre-mining concentrations could increase by 10 to 20 percent during periods of low flow.

Evaluations here are not based upon hard data from the proposed mine site, nor do they address related questions such as river transport of sediments, trace elements, and nutrients. Geochemical data from the site should be obtained and interpreted, and a carefully-emplaced monitoring program should be established to determine actual changes when mining begins.

INTRODUCTION

Sage Creek Coal Limited has announced intentions of developing a thermal coal mining operation in British Columbia within six miles of the International Border with Montana. The coal deposits occur within the Jurassic-Cretaceous Kootenay Formation near the southern extension of the Flathead coal area. The project will be a truck/shovel operation ; mining is planned from two open pits that are designated as the North Hill and the

South Hill.

The proposed mine has aroused many environmental concerns, including the uncertainty of pollution from acid-mine drainage. Acid-mine drainage is a direct result of weathering of sulfide-rich shales, sandstones and coals. Previous studies have determined that, when present, acid-mine drainage water can contaminate surface- and ground-water resources for extended periods. Geochemical and hydrologic conditions that enhance acid production and associated pollution are highly site specific. Many coal mines produce non-acidic drainage waters; others however, such as the abandoned mines that produced Cretaceous-age coal near Great Falls, Montana (220 miles to the southeast) now produce highly acid waters that cause serious pollution to streams and ground water. Whether acidic or alkaline, drainage from mine dumps or spoils very commonly carries increased concentrations of dissolved solids; off-site effects of these increases are highly dependent upon natural dilution. Nearness of the proposed mine to the Montana border and to the south-flowing North Fork of the Flathead River prompted this brief examination of potential acid production and dissolved solids'generation at the proposed Sage Creek mine site.

For this limited study, primary objectives have been to address potential for acidic drainage and increased dissolved solids from the proposed Sage Creek Project. Secondary objectives were to obtain additional pre-mining water-quality data that might have future value in more detailed assessments of hydrologic conditions, and to compile a bibliography of relevant literature. The new data collected here will hopefully also augment and reinforce data collected by Canadian investigators during previous studies.

Acknowledgements

The authors wish to acknowledge the following individuals, firms and agencies for their support and for access to their lands: Mr. C. William McK. Burge, Lornex Mining Corporation Limited; Mr. T.W. Hannah and Mr. H. Brent Densmore, CrowsNest Resources Limited; Dr. G. Lynn Taylor and Mr. Gene Mickelson, Westar Mining Limited; Mr. Dave Grieve, Ministry of Energy, Mines and Petroleum Resources, Province of British Columbia; Dr. Frank Abercrombie, Montana Bureau of Mines and Geology; and Mr. John R. Davis for his field assistance.

Previous Research

The proposed Sage Creek Coal site has been studied extensively by consultants to assess environmental conditions and to predict future problems. The bibliography of this report includes these earlier assessments. Potential for acid drainage was not rigorously addressed in those studies, however, and potential for off-site increases in dissolved-solids concentrations received even less attention. Indirectly, acid potential was addressed by Jackson (1982) in a survey of coal mine leachates of that region. He found increased sulfate concentrations with apparent corresponding decreased alkalinities in leachates from the Kootenay Formation at two mine dumps, both within 40 miles north of the Sage Creek site. Sulfur oxidation is probably occurring in those materials, but the resulting acid is being neutralized at the expense of some alkalinity. Overall, Jackson's evaluation of twelve sites in the Canadian Rocky Mountain Foothills and Front Ranges found mine-drainage waters ranging from alkaline to slightly acidic. Hackbarth (1979) documented increases in dissolved solids in non-acidic leachates from a mine in west-central Alberta. This is a

common effect of mining in Montana and North Dakota, and can be expected to occur at the proposed Sage Creek Project.

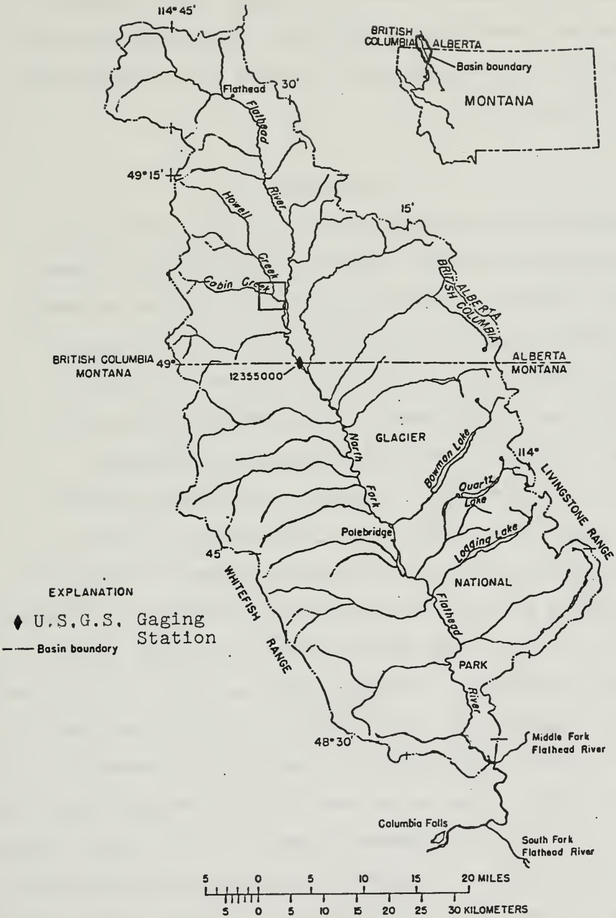
LOCATION AND PHYSIOGRAPHY

The proposed Sage Creek Coal mine is located within the southern portion of the Flathead Coal Area of British Columbia, approximately six miles north of the International Boundary (Figure 1). The two proposed mine pits (North Hill and South Hill) are separated by Cabin Creek, an east-flowing tributary of Howell Creek which flows into the North Fork of the Flathead River. The Flathead River flows southward across the International Boundary into the State of Montana.

The site is on the east side of the Flathead Valley, near the toe of the east flank of the MacDonald Range. In this area, rugged and relatively bare peaks give way to lower, steep subrounded, heavily forested hills with elevations ranging from 4,100 to 5,315 feet. The eastern edge of the mine site is on the relatively flat floor of the river valley which is thinly wooded. The western edge of the site is on irregular, sloping ground that is densely wooded. Tops of the North and South hills are approximately 1,000 feet above the valley floor (Stage II Environmental Assessment, 1982).

GEOLOGIC SETTING

The Sage Creek coal deposits occur within a localized thrust remnant. It has been preserved from erosion by subsequent normal faulting between two resistant thrust blocks, the eastern Clark Range and the western MacDonald Range. The strata form an east-dipping monocline with an average



Location Map of Study Area

Figure 1

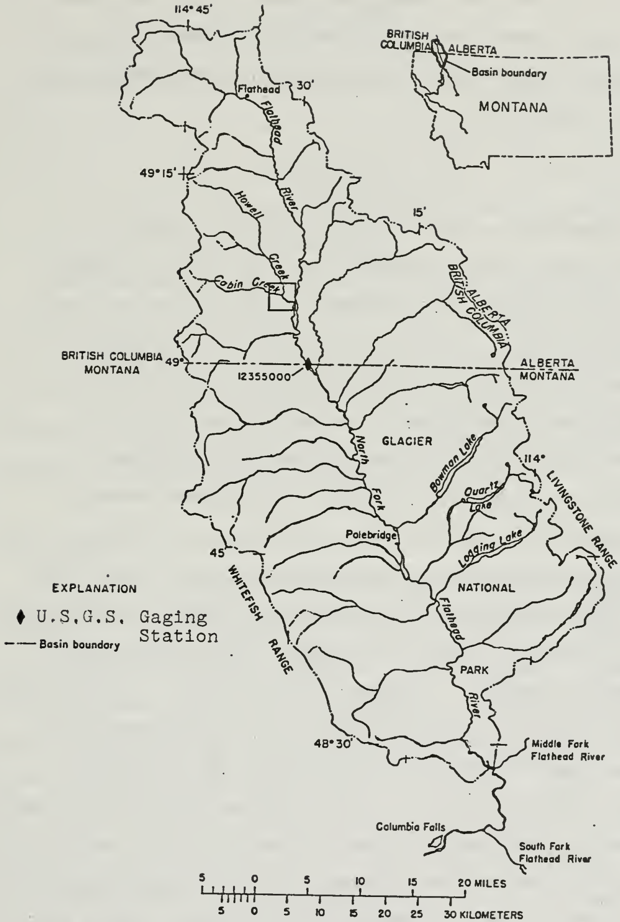
dip of about 30° and have a general north-south strike. The strata extend eastward downdip beneath the floor of the Flathead Valley and are truncated along the west edge of the valley by the Flathead Fault, a listric normal fault.

STRATIGRAPHY

The Sage Creek coal beds occur within the lower portion of the Kootenay Formation (Canadian nomenclature). The Jurassic-Cretaceous Kootenay is non-marine. It unconformably overlays the marine Jurassic Fernie Formation, and is disconformably overlain by the non-marine Cretaceous Blairmore Group. Progressing upsection, the Tertiary Kishenehn Formation unconformably overlies Cretaceous strata, and Quaternary glacial and alluvial deposits mantle the Kishenehn.

Within the project area, thickness of the Kootenay Formation varies between 650 to 850 feet (Pacific Hydrology Ltd., 1982) as determined from drill hole data and measured sections. A basal sandstone, formally designated as the Moose Mountain Member, is the Kootenay's basal unit. Above the Moose Mountain Member, the Kootenay beds are sandstones, conglomerates, siltstones, shales and coals. The top of the Formation is capped by the basal conglomerate of the Blairmore Group.

Sage Creek Coal Limited has determined that three economically accessible coal beds occur on the property and has designated them "seams 2, 4, and 5". Seam 2 has an average thickness of 15 feet. Seam 4 occurs as two distinct benches; the upper bench has an average thickness of 30 feet, and the lower has an average thickness of 18 feet. Seam 5 also normally occurs as two benches; the upper has an average thickness of 16 feet and the lower has an average thickness of 19 feet (Stage II Environmental Assessment, 1982).



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WATER QUALITY

One objective of this study was to obtain pre-mining water quality data that can be used to characterize the waters in relation to current standards and to determine water-quality changes subsequent to mining operations. The chemical analyses were performed by the Montana Bureau of Mines and Geology's Analytical Division according to established U.S. Geological Survey (1979) procedures.

Water samples were collected during low summer flows on Howell Creek and Cabin Creek, and from seven wells. The field parameters temperature, pH, specific conductivity and alkalinity were measured during sample collection. All samples were analyzed for major anions and cations, nutrients, a suite of trace metals, and hydrogen sulfide. Appendix I contains the complete analysis performed on each sample.

Ground Water

The wells sampled are converted core holes, generally completed with 6 inch steel casing. Ground water flows from 6 of the wells; these are all completed in the Kootenay Formation. The seventh well is completed in the Kishenehn Formation and has a static water level about three feet below land surface. Waters derived from the Kootenay and Kishenehn Formations have different chemical characteristics.

Temperatures and pH values of water from the Kootenay Formation ranged from 6.0 to 9.0°C and 6.75 to 7.25, respectively (Table 1). Calculated dissolved solids ranged from 203 to 263 mg/L (milligrams/liter). Kootenay Formation waters can be typified as calcium/magnesium bicarbonate type (Figure 2), with calcium concentrations generally twice those of magnesium. Iron was the only constituent present having higher concentrations

TABLE 1
SELECTED WATER-QUALITY PARAMETERS

Lab Number	Source	Field pH	Field Temp °C	Calculated D.S.	Fe*	Mn*	PO_4^{*-2}	Total P*	Total N*
84Q0667	Kk[1]	6.75	7.0	255	0.79	.018	<.1	<.1	1.22
84Q0668	Tk[2]	8.37	19.5	277	0.023	.066	<.1	<.1	0.20
84Q0669	Kk	6.98	9.0	233	0.42	.018	0.2	.2	0.13
84Q0670	Kk	6.83	8.0	263	2.95	.050	<.1	<.1	0.06
84Q0671	Kk	7.25	6.0	203	0.65	.014	0.2	.4	0.06
84Q0672	Kk	7.18	6.0	228	0.52	.037	<.1	<.1	0.08
84Q0673	Kk	7.11	6.0	218	0.27	.016	0.2	.5	0.21
84Q0688	HC[3]	7.18	13.5	144	<.002	.001	<.1	<.1	0.06
84Q0689	CC[4]	8.22	17.5	144	<.002	.002	<.1	<.1	0.22

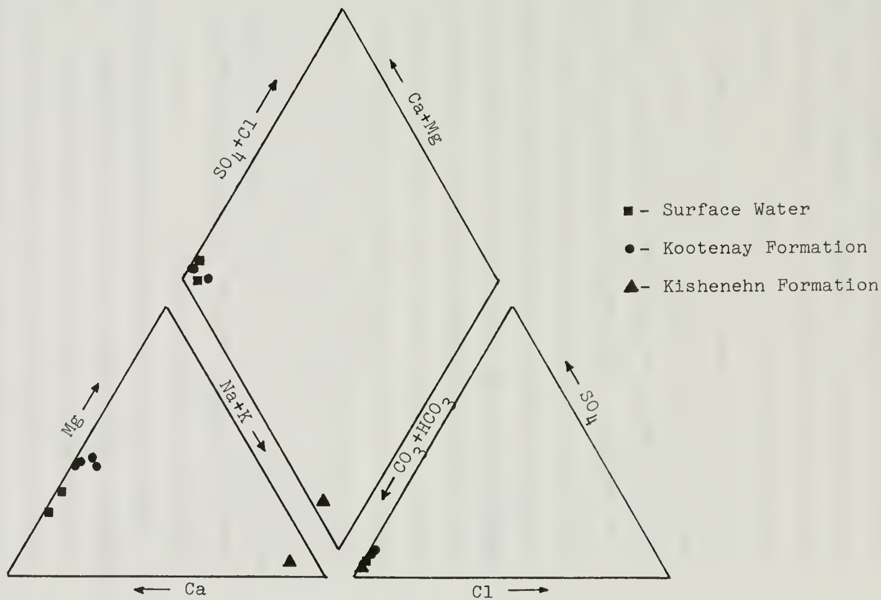
[1] Kk - Cretaceous Kootenay Formation

[2] Tk - Tertiary Kishenehn Formation

[3] HC - Howell Creek

[4] CC - Cabin Creek

* reported as milligrams per liter



Piper plot of major element chemistry for waters from Table I.
Figure 2

than the U.S. EPA's recommended drinking standards of 0.3 mg/L. Iron values varied from 0.27 to 2.95 mg/L. Veneers of ferric oxide on the well-heads and surrounding ground surface suggest that the iron is from the aquifer rather than the casing, and is now precipitating because of increased dissolved-oxygen concentrations in the water as it moves from confined to atmospheric-pressure conditions.

Water sampled from the Kishenehn Formation is different from that of the Kootenay. Higher temperature and pH were found, 19.5°C and 8.37 respectively. Calculated dissolved solids were 277 mg/L, of which sodium was the major cation and bicarbonate the major anion (Figure 2). Montmorillinitic clay of this formation is a probable source of the sodium, either directly from leaching or possibly by exchange for calcium and magnesium in recharge waters from the deeper but more highly pressured Kootenay Formation. Wildlife, particularly deer and moose, prefer to drink water from the casings of holes completed in the Kishenehn Formation over those in the Kootenay wells, perhaps for the sodic salts. Kishenehn water appears to contain a negligible amount of iron relative to that present in Kootenay water, possibly because of differences in ferrous carbonate (siderite) solubility.

Ground-water samples were also analyzed for the nutrients nitrate, dissolved total phosphate and dissolved ortho-phosphate. With one exception, nitrate concentrations (as N) were less than 0.25 mg/L. The highest concentrations of total- and ortho-phosphate (as P) were 0.5 and 0.2 mg/L, respectively; however most of the concentrations were near the detection limit of 0.1 mg/L for both nutrients.

Concentrations of dissolved trace metals in all samples were generally low, and frequently below the limits of laboratory detection.

Boron, strontium and occassionally lithium,were present in generally larger concentrations than other trace metals, but at insignificant levels.

Surface Water

Water samples were collected on July 31, 1984 from Howell and Cabin Creeks near their confluence using depth-integrated sampling procedures. Discharge measurements were not made at the times of sampling, but flows were judged to be low, being sustained by ground-water discharge. Dissolved-solids contents in both samples (144 mg/L) were substantially lower than those found in nearby ground water. In terms of relative concentrations of specific constituents, the waters were calcium-magnesium bicarbonate predominant, similar to Kootenay water (Figure 2).

POTENTIAL FOR ACID MINE DRAINAGE

The work plan for this study was initially designed to analyze rock samples collected from outcrops at the proposed Sage Creek mine site, however, poor exposures and the weathered nature of the Kootenay Formation precluded collection of suitable samples. It was also hoped that drill core from the proposed mine would be available, but none could be obtained. As an additional complication, rocks south of the International Border are not equivalent to those at the proposed mine, so representative cores could not be obtained in Montana. Mines in the Elk Valley and Crowsnest Coal Fields of southeastern British Columbia produce from deposits equivalent to those in the Flathead Coal Area, however, and representatives from CrowsNest Resources Limited's Line Creek Mine (Elk Valley Coal Field) and from Westar Limited's Harmer Ridge Mine (CrowsNest Coal Field) consented to provide samples.

The Line Creek Mine is located in the southern half of the Elk Valley Coal Field, approximately 7.5 miles northeast of Sparwood, British Columbia. Lithologies there are analogous to those at the Sage Creek site, both consisting predominantly of silicic sediments with interbedded coal beds. Coals at the Line Creek Mine and the Sage Creek site have a medium-volatile bituminous rank, and have almost identical characteristics (Table 2). These similarities of coal characteristics and interburden lithologies suggest that Line Creek overburden analyses might suffice for estimating acid potential at the study site. Samples collected from the Line Creek Mine for this study were obtained from a fresh face on the pit highwall, and represent approximately 750 feet of coal interburden and overburden.

The Harmer Ridge Mine is located approximately 3 road miles northeast of Sparwood, British Columbia, on the northern edge of the CrowsNest Coal Field. Lithologies at the Harmer Ridge and Sage Creek sites are highly similar. At both, the base of the Kootenay Formation is delineated by a sandstone known as the Moose Mountain Member. It is 100 to 110 feet thick and underlies a sequence of sandstones, siltstones, and shales interbedded with coal. From numerous core logs, a hole was selected that had penetrated most of the Kootenay section at the Harmer Ridge Mine, and splits of the core from that hole were analyzed. Stratigraphic thickness represented by the samples is about 600 feet.

Analytical Procedures

Bulk samples were crushed to less than ½ inch in diameter and a representative sample was split out using a riffle splitter. Each of these samples was then pulverized to pass a 100 mesh screen.

TABLE 2

CLEAN COAL ANALYSIS

(air dried)

	Cabin Creek Mine	Line Creek Mine
Ash (%)	16.2	14 - 17
Residual Moisture (%)	0.9	0.95
Sulfur (%)	0.5*	0.31
Volatile Matter (%)	22.6	21.8
Fixed Carbon (%)	60.3	61.9
Calorific Value (Btu/lb)1	12,510.0	12,400.0

1 Sage Creek Coal Limited's Stage II Environmental Assessment

2 Gilmar, Patrick C., 1984, Line Creek Extension

* - Montana Bureau of Mines and Geology's analysis was 0.24% Sulfur

The pulverized samples were assayed in duplicate to determine total sulfur, using the Leco furnace method. The total sulfur assay values are expressed as pounds of sulfuric acid per ton of sample, assuming a 1:1 conversion factor, which is the acid-production potential of the sample.

Duplicate 10-gram portions of the pulverized samples were each suspended in 100 ml (milliliters) of distilled water and stirred for approximately 15 minutes. pH values of the samples were recorded, and the samples were then titrated to a pH of 5.0 for one hour and a pH of 3.5 for three hours with 1.0 N sulfuric acid using an automatic titrator. Total volume of acid for each pH level, converted to lb/ton (pounds per ton) of sample, is the acid-consuming ability of the sample, i.e.:

$$\text{acid-consuming ability (lb/ton)} = \frac{\text{ml of 1.0 N } H_2SO_4 \times 0.049 \times 2000}{\text{wt of sample in g}}$$

$$\text{or for a 10-gram sample} = \text{ml of 1.0 N } H_2SO_4 \times 9.8$$

If the acid-consumption potential exceeds the acid-production potential, the sample should not be a source of acid drainage. If it is lower, the possibility of acid mine water production exists.

Results

The 750-foot-thick stratigraphic column sampled at the Line Creek Mine was composited into 7 samples. Analyses of those (Table 3) showed that potential to consume acid (at pH=5.0) greatly exceeded potential to generate acid. Ratios varied from a low of 3.3:1 to a high of 56:1, and had a mean value of 15:1. The data are graphically displayed in Figure 3. At a minimum, the acid-consuming ability of the rock is three times greater than its acid-producing ability.

TABLE 3

ACID PRODUCTION - CONSUMPTION RESULTS

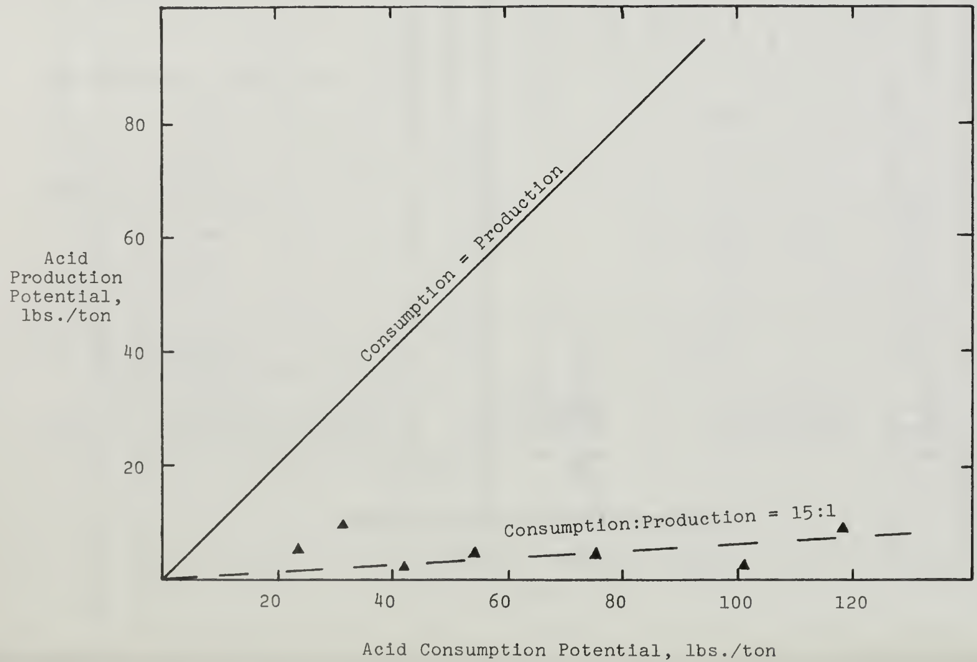
CROWSNEST RESOURCES LIMITED'S LINE CREEK MINE

Sample	Natural pH	Total % Sulfur	Acid Production Potential lbs/t	Acid Consumption* Potential lbs/t	Potential Acid Producer
10B - 9L	8.27	0.08	4.9	75.5	No
9L - 9U	8.13	0.10	6.1	24.0	No
9U - 8	8.50	0.03	1.8	42.2	No
8 - marker	8.48	0.03	1.8	101.0	No
marker - 7	8.29	0.16	9.8	32.4	No
7 - 6L	7.70	0.08	4.9	54.9	No
6U - 5	8.65	0.15	9.2	119.0	No

* Consumption for 1 hour at a pH of 5.0

Figure 3

LINE CREEK MINE



Identical test procedures were used for the samples derived from the Harmer Ridge Mine. Splits of core representing the 600-foot-thick stratigraphic column were composited into 12 samples for analysis. The test results (Table 4) are not significantly different from those for the Line Creek samples. Samples 212-196 and 196-166 had the lowest acid consumption/production ratios, 1.9:1 and 2.6:1, respectively. These rock samples were predominantly shales near thin coal seams; the high percentages of total sulfur likely relate to lithology and stratigraphic position. Sample 660-611 contains the highest percentage of sulfur (0.35), but has a buffering ratio of 3.7:1. This sample was dominantly sandstone, cemented with calcite. Overall, the samples had a mean acid consumption/production ratio of about 8:1 (Figure 4).

Results shown on Tables 3 and 4 are for titrations to a pH level of 5.0. This procedure is more environmentally sensitive than the earlier work (Stage II Environmental Assessment, 1982, Appendix 4.3.5-1) in which titrations were made to a pH of 3.5. In this study, titrations to the lower end point (not presented) confirmed the earlier work. That confirmation, plus this worst-case evaluation strongly indicate that there is no likelihood of acid drainage from the proposed mine.

POTENTIAL OFF-SITE INCREASES IN DISSOLVED SOLIDS

In evaluating leachates from mine dumps or spoils, the effects of increased dissolved solids must be addressed. Documentations of such changes at surface mines are plentiful over wide ranges of geologic and hydrologic conditions, whether drainage waters are acidic or alkaline. Two-to-three fold increases in dissolved solids concentrations in surface-coal mine leachates have been described at numerous sites in Montana

TABLE 4

ACID PRODUCTION - CONSUMPTION RESULTS

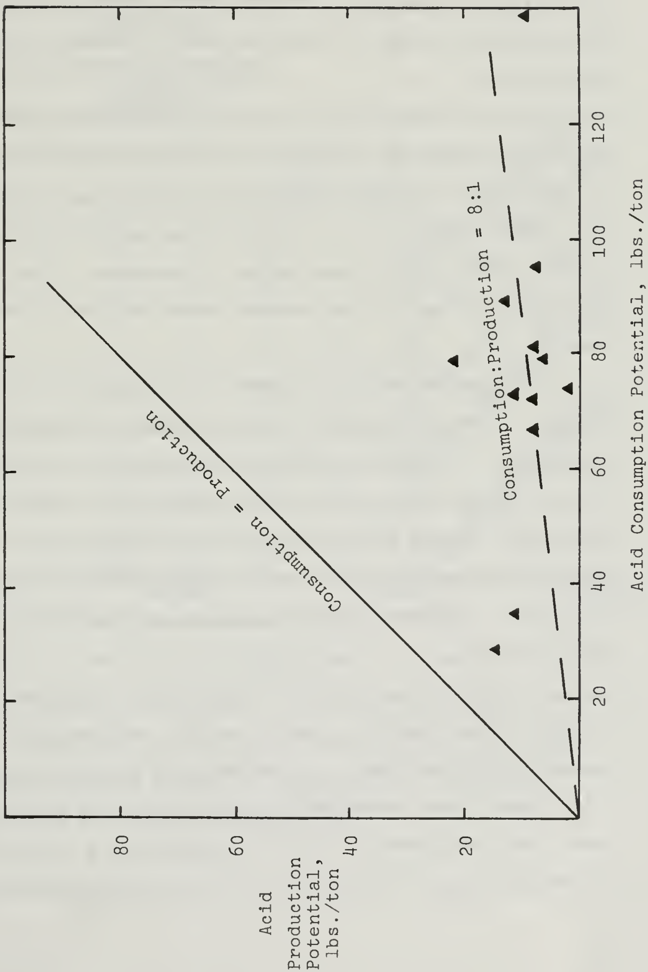
WESTAR MINING COMPANY'S HARMER RIDGE MINE

Sample	Natural pH	Total % Sulfur	Acid Production Potential lbs/t	Acid Consumption Potential lbs/t*	Potential Acid Producer
660 - 611	8.37	0.35	21.4	79.9	No
611 - 556	8.50	0.11	6.7	80.4	No
556 - 542	8.65	0.13	8.0	82.8	No
542 - 500	8.79	0.17	10.4	141.0	No
500 - 390	8.80	0.21	12.9	90.7	No
390 - 318	8.93	0.13	8.0	96.1	No
318 - 212	8.58	0.03	1.8	74.8	No
212 - 196	8.04	0.25	15.3	29.5	No
196 - 166	7.95	0.22	13.5	35.8	No
166 - 108	8.44	0.19	11.6	74.0	No
108 - 94	8.43	0.15	9.2	73.2	No
94 - 51	8.76	0.14	8.6	68.1	No

* Consumption for 1 hour at a pH of 5.0

Figure 4

HARMER RIDGE MINE



(Van Voast and others, 1978) and in North Dakota (Groenewold and others, 1983). More specific to the Flathead Coal Area are similar findings by Hackbarth (1979) at a mine near Grand Cache in west-central Alberta. There he found concentrations of major constituents elevated to four-times background values, and found even greater increases in nitrate concentrations.

There are no data with which to specifically assess probable salinities of leachates from dumps at the proposed Sage Creek site, or to estimate offsite effects. A non-rigorous exercise was conducted in this study, however, to find a perspective that might help planners determine whether further investigations are necessary. Those decisions, of course, will require value judgements beyond the scope of the present work.

To determine a perspective, several rough assumptions are necessary. Here, an increase in dissolved solids of 600 mg/L (a four-fold increase over pre-mining concentrations) was assumed for dump leachates. This was mass-balanced into selected flow conditions for Howell Creek below Cabin Creek and for the North Fork of the Flathead River to demonstrate possible associated dissolved-solids increases in the receiving streams (Figure 5). A range of leachate discharge rates between 25,000 and 125,000 cubic feet per day, corresponding to infiltration rates of 1 to 5 inches per year, on the proposed 2540 acres of mine dumps is considered likely in this exercise. Under the given assumptions, leachates would probably create no detectable changes in dissolved-solids concentrations in the river. Howell Creek below Cabin Creek could conceivably gain about 25 mg/L under a worst case condition of low flow augmented by a high rate of leachate discharge. This could be a 10 to 20 percent increase over background

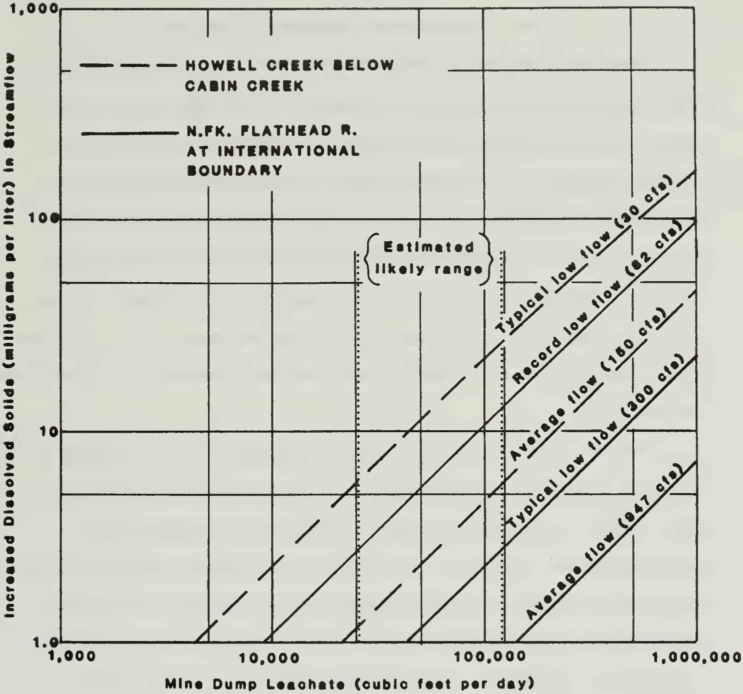


Figure 5

Approximations of possible dissolved-solids increases in Howell Creek and in N. Fk. Flathead River that might result from leachates from mine dumps at the Sage Creek site. Streamflow rates (cfs) are in cubic feet per second.

dissolved-solids concentrations.

DISCUSSION AND RECOMMENDATIONS

Although overburden and interburden samples could not be obtained at the Sage Creek site, samples from surface coal mines north of there were considered as useful indicators of acid-production potential that might be present at the proposed mine. Acid consumption/production ratios for a 750-foot-thick stratigraphic sequence at the Line Creek Mine, and a 600-foot sequence at the Harmer Ridge Mine indicate that all acid produced by sulfide oxidation should be neutralized by natural buffering capacities. It appears likely that drainage from the mine may range from alkaline to slightly acidic, similar to waters from other mines of the region.

Another concern, that of increased dissolved solids in streams that receive leachates from the proposed mine dumps, was also considered in this study. Under somewhat tenuous assumptions, it appears that dissolved-solids increases in the North Fork of the Flathead River would probably be too small to be detectable at the International Boundary. In Howell Creek below the mouth of Cabin Creek, however, dissolved solids concentrations could be increased by 10 to 20 percent during periods of low flow. Significance of such changes is left to the judgement of others.

The results of this study are not based upon real geochemical data from the proposed Sage Creek mine, but upon projections that allow the roughest of approximations. Given the site-specific nature of geochemical conditions, verification of these results with real data from the site would be highly important.

Other hydrologic concerns over the proposed project include increased

river transport of nutrients, trace elements, and sediments across the International Boundary. These have been addressed heavily through research and design by project consultants, and reach far beyond the scope of this limited study. Regardless of attention during planning, monitoring before, during, and after the proposed mining will give the only real answers to some of these concerns. A long-term, carefully emplaced surface- and ground-water monitoring program is therefore strongly recommended so that we may at the very least have clearer judgement in the future.

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APPENDIX I

Water-Quality Analyses

Note: The raw data resulting from water analysis for this project can be obtained from:

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309 Montana Hall
Montana State University
Bozeman, MT 59717
phone (406) 994-6690